PATENT APPLICATION
Attorney Docket: 2890 (203-3438)

MOTION DETECTOR FOR CONTROLLING ELECTROSURGICAL OUTPUT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of and priority to U.S. Provisional Patent Application No. 60/448,520, filed on February 20, 2003, and U.S. Provisional Patent Application No. 60/533,695, filed January 1, 2004, the entire contents of which are incorporated herein by reference.

BACKGROUND

Technical Field

[0002] The present disclosure relates generally to an electrosurgical instrument and, more particularly, to an electrosurgical pencil having a motion detector for controlling the electrosurgical output thereof.

Background of Related Art

[0003] Electrosurgical instruments have become widely used by surgeons in recent years. Accordingly, a need has developed for equipment that is easy to handle, is easy to operate, and is reliable and safe. By and large, most surgical instruments typically include a variety of hand-held pencils, e.g., electrosurgical pencils, forceps, scissors and the like, and electrosurgical pencils, which transfer energy to a tissue site. The electrosurgical energy is initially transmitted from an

electrosurgical generator to an active electrode which, in turn, transmits the electrosurgical energy to the tissue. In a monopolar system, a return electrode pad is positioned under the patient to complete the electrical path to the electrosurgical generator. A smaller return electrode is positioned in bodily contact with or immediately adjacent to the surgical site in a bipolar system configuration.

[0004] For the purposes herein, the term electrosurgical fulguration includes the application of an electric spark to biological tissue, for example, human flesh or the tissue of internal organs, without significant cutting. The spark is produced by bursts of radio-frequency electrical energy generated from an appropriate electrosurgical generator. Generally, electrosurgical fulguration is used to dehydrate, shrink, necrose or char tissue. As a result, electrosurgical fulguration instruments are primarily used to stop bleeding and oozing of various surgical fluids. These operations are generally embraced by the term "coagulation." Meanwhile, electrosurgical "cutting" includes the use of the applied electric spark to tissue which produces a cutting effect. By contrast, electrosurgical "sealing" includes utilizing a unique combination of electrosurgical energy, pressure and gap distance between electrodes to melt the tissue collagen into a fused mass.

[0005] It is known that certain electrosurgical waveforms are preferred for different surgical effects. For example, a continuous (i.e., steady) sinusoidal waveform is preferred to enhance the cutting effect of the electrosurgical blade in an electrosurgical pencil or enhance the cooperative effect of the two opposing

jaw members. A series of discontinuous, high energy electrosurgical pulses are preferred to enhance the coagulation of biological tissue. Other types of electrosurgical waveforms are preferred for electrosurgical "blending", "shorting" or fusing tissue. As can be appreciated, these waveforms are typically regulated by the generator and are generally dependent upon the desired mode of operation manually selected by the surgeon at the onset (or during) the operation.

[0006] As used herein, the term "electrosurgical pencil" is intended to include instruments which have a handpiece which is attached to an active electrode and are used to coagulate, cut, and seal tissue. The pencil may be operated by a hand-switch (in the form of a depressible button provided on the handpiece itself) or a foot-switch (in the form of a depressible pedal operatively connected to the handpiece). The active electrode is an electrically conducting element which is usually elongated and may be in the form of a thin flat blade with a pointed or rounded distal end. Typically, electrodes of this sort are known in the art as "blade" type. Alternatively, the active electrode may include an elongated narrow cylindrical needle which is solid or hollow with a flat, rounded, pointed or slanted distal end. Typically, electrodes of this sort are known in the art as "loop" or "snare", "needle" or "ball" type.

[0007] As mentioned above, the handpiece of the pencil is connected to a suitable electrosurgical source (e.g., generator) which supplies the electrosurgical energy necessary to the conductive element of the electrosurgical pencil. In general, when an operation is performed on a patient with an

electrosurgical pencil, energy from the electrosurgical generator is conducted through the active electrode to the tissue at the site of the operation and then through the patient to a return electrode. The return electrode is typically placed at a convenient place on the patient's body and is attached to the generator by a return cable.

[0008] During the operation, the surgeon depresses the hand-switch or foot-switch to activate the electrosurgical pencil. Then, depending on the level of radio-frequency electrosurgical energy desired for the particular surgical effect, the surgeon manually adjusts the power level on the electrosurgical generator by, for example, rotating a dial on the electrosurgical instrument. Recently, electrosurgical pencils have been developed which vary the level of electrosurgical energy delivered depending on the amount of drag sensed by the active electrode or by the degree the hand-switch has been depressed by the surgeon. Examples of some of these instruments are described in commonly assigned U.S. Provisional Application Nos. 60/398,620 filed July 25, 2002 and 60/424,352 filed November 5, 2002, the entire contents of which are hereby incorporated by reference.

[0009] Accordingly, a need exists for an electrosurgical pencil which is activated without the use of hand-switches or foot-switches and which can automatically control the electrosurgical output from the electrosurgical generator without manual intervention by the surgeon.

SUMMARY

[0010] An electrosurgical instrument having a movement sensing device for controlling the electrosurgical output thereof, is disclosed. In one aspect of the present disclosure, the electrosurgical instrument includes an elongated housing, an electrically conductive element supported within the housing and extending distally from the housing, the electrically conductive element being connectable to a source of electrosurgical energy, and a sensor disposed within the housing and in electrical connection with the electrosurgical generator. The sensor detects movement of the electrically conductive element and communicates a signal to the electrosurgical generator relating to the movement of the electrically conductive element. The source of electrosurgical energy supplies electrosurgical energy in response to the signal communicated from the sensor.

[0011] It is envisioned that the sensor for detecting movement of the electrically conductive element is at least one of force-sensing transducers, accelerometers, optical positioning systems, radiofrequency positioning systems, ultrasonic positioning systems and magnetic field positioning systems.

[0012] Preferably, the electrically conductive element includes a longitudinal axis defined therethrough and the sensor detects at least one of a axial movement of the electrically conductive element along the longitudinal axis, a transverse movement across the longitudinal axis of the electrically conductive element, and a rotational movement about the longitudinal axis of the electrically

conductive element. In one embodiment it is envisioned that the source of electrosurgical energy transmits a dissecting RF energy output in response to the detection of axial movement of the electrically conductive element along the longitudinal axis. In another embodiment it is envisioned that the source of electrosurgical energy transmits a hemostatic RF energy output in response to the detection of transverse movement of the electrically conductive element across the longitudinal axis.

[0013] It is envisioned that the sensor is at least one of a differential parallel plate accelerometer, a balanced interdigitated comb-finger accelerometer, an offset interdigitated comb-finger accelerometer and a film-type accelerometer. Preferably, the sensor includes a first accelerometer for detecting a movement of the electrically conductive element in an axial direction along the longitudinal axis and a second accelerometer for detecting movement of the electrically conductive element in a transverse direction across the longitudinal axis. It is also envisioned that the sensor may include at least one piezoelectric film.

[0014] In one embodiment it is contemplated that the first accelerometer is configured and adapted to transmit an output signal to the electrosurgical energy source corresponding to the axial movement of the electrically conductive element, and the second accelerometer is configured and adapted to transmit an output signal to the electrosurgical energy source corresponding to the transverse movement of the electrically conductive element. Preferably, each of the first and second accelerometers is at least one of a differential parallel plate

accelerometer, a balanced interdigitated comb-finger accelerometer, an offset interdigitated comb-finger accelerometer and a film-type accelerometer.

[0015] In certain embodiments it is envisioned that the source of electrosurgical energy ceases supplying electrosurgical energy when the sensor does not detect a movement of the electrosurgical pencil for a predetermined period of time and/or does not detect a movement of the electrosurgical pencil above a predetermined threshold level of movement.

[0016] It is further envisioned that in certain embodiments the source of electrosurgical energy resumes supplying electrosurgical energy when the sensor detects a movement of the electrosurgical pencil following the predetermined period of time and/or detects a movement of the electrosurgical pencil above the predetermined threshold level of movement.

[0017] These and other objects will be more clearly illustrated below by the description of the drawings and the detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings, which are incorporated and constitute a part of this specification, illustrate embodiments of the disclosure and, together with a general description of the disclosure given above, and the detailed description of the embodiments given below, serve to explain the principles of the disclosure.

[0019] FIG. 1 is a partially broken away side, elevational view of an embodiment of the electrosurgical pencil in accordance with the present disclosure;

[0020] FIGS. 2A-2C illustrate three embodiments of accelerometers suitable for in-plane sensing or forcing;

[0021] FIG. 3 is a partially broken away perspective view of an electrosurgical pencil in accordance with another embodiment of the present disclosure; and

[0022] FIG. 4 is an enlarged perspective view of the indicated area of FIG. 3.

DETAILED DESCRIPTION

[0023] Embodiments of the presently disclosed electrosurgical pencil will now be described in detail with reference to the drawing figures wherein like reference numerals identify similar or identical elements. In the drawings, and in the description which follows, as is traditional, the term "proximal" will refer to the end of the electrosurgical pencil which is closest to the operator, while the term "distal" will refer to the end of the electrosurgical pencil which is furthest from the operator.

[0024] Acceleration is a physical quality which often must be sensed or measured. Acceleration is defined as the rate of change of velocity with respect to time. For example, acceleration is often sensed to measure force or mass, or

to operate some kind of control system. At the center of any acceleration measurement is an acceleration-sensing element, or force-sensing transducer. The transducer is often mechanical or electromechanical element (e.g., a piezo-electric transducer, a piezo-resistive transducer or a strain gauge) which is typically interfaced with an electrical signal or electrical circuits for providing a useful output signal to a generator, computer or other surgical console. Exemplary transducers are described in U.S. Pat. Nos. 5,367,217, 5,339,698, and 5,331,242, the entire contents of which are incorporated herein by reference. An accelerometer is defined as an instrument which measures acceleration or gravitational force capable of imparting acceleration. Another type of force-sensing transducer is an accelerometer. Exemplary accelerometers are described in U.S. Pat. Nos. 5,594,170, 5,501,103, 5,379,639, 5,377,545, 5,456,111, 5,456,110, and 5,005,413, the entire contents of which are incorporated herein by reference.

[0025] Several types of accelerometers are known. A first type of accelerometer incorporates a bulk-micromachined silicon mass suspended by silicon beams, wherein ion-implanted piezo-resistors on the suspension beams sense the motion of the mass. A second type of accelerometer utilizes a change in capacitance to detect movement of the mass. A third type of accelerometer detects acceleration by measuring a change in a structure's resonant frequency as a result of a shift in the physical load of the structure. It is envisioned that the accelerometers can include a piezoelectric film sandwiched into a weighted printed flex circuit. It is also envisioned that at least one resistive flex circuit

could be used to detect the position and/or orientation of the surgical instrument rather than acceleration.

[0026] Turning now to FIG. 1, there is set forth a partially broken away side, elevational view of an electrosurgical pencil constructed in accordance with an embodiment of the present disclosure and generally referenced by numeral 100. While the following description will be directed towards electrosurgical pencils, it is envisioned that the features and concepts of the present disclosure can be applied to other electrosurgical instruments, e.g., dissectors, ablation instruments, probes, etc. Electrosurgical pencil 100 includes an elongated housing 102 configured and adapted to support a blade receptacle 104 at a distal end 103 thereof which, in turn, receives an electrocautery blade 106 therein. A distal end 108 of blade 106 extends distally from receptacle 104 while a proximal end 110 of blade 106 is retained within the distal end 103 of housing 102. Preferably, electrocautery blade 106 is fabricated from a conductive material, e.g., stainless steel or aluminum or is coated with an electrically conductive material.

[0027] As shown, electrosurgical pencil 100 is coupled to a conventional electrosurgical generator "G" via a cable 112. Cable 112 includes a transmission wire 114 which electrically interconnects electrosurgical generator "G" with proximal end 110 of electrocautery blade 106. Cable 112 further includes a control loop 116 which electrically interconnects a movement sensing device 124 (e.g., an accelerometer), supported within housing 102, with electrosurgical generator "G".

[0028] By way of example only, electrosurgical generator "G" may be any one of the following, or equivalents thereof: the "FORCE FX", "FORCE 2" or "FORCE 4" generators manufactured by Valleylab, Inc., a division of Tyco Healthcare, LP, Boulder, Colorado. Preferably, the energy output of electrosurgical generator "G" can be variable in order to provide appropriate electrosurgical signals for tissue cutting (e.g., 1 to 300 watts) and appropriate electrosurgical signals for tissue coagulation (e.g., 1 to 120 watts). One example of a suitable electrosurgical generator "G" is disclosed in commonly-assigned U.S. Patent No. 6,068,627 to Orszulak, et al., the entire contents of which are incorporated herein by reference. The electrosurgical generator disclosed in the '627 patent includes, *inter alia*, an identifying circuit and a switch therein. In general, the identification circuit is responsive to the information received from a generator and transmits a verification signal back to the generator. Meanwhile, the switch is connected to the identifying circuit and is responsive to signaling received from the identifying circuit.

[0029] Electrosurgical pencil 100 further includes an activation button 126 supported on an outer surface of housing 102. Activation button 126 is operable to control a depressible switch 128 which is used to control the delivery of electrical energy transmitted to electrocautery blade 106.

[0030] Turning back to FIG. 1, as mentioned above, electrosurgical pencil 100 includes an accelerometer 124 which is supported within housing 102. Accelerometer 124 is operatively connected to generator "G" which, in turn, controls and transmits an appropriate amount of electrosurgical energy to

electrocautery blade 106 and/or controls the waveform output from electrosurgical generator “G”.

[0031] In use, the surgeon activates electrosurgical pencil 100 by depressing activation button 126 thereby allowing electrical energy to be transmitted to electrocautery blade 106. With activation button 126 depressed, as the surgeon moves electrosurgical pencil 100 repeatedly along the X axis (i.e., in a stab-like motion), as indicated by double-headed arrow “X” in FIG. 1, accelerometer 124 transmits a corresponding signal, through control loop 116, to generator “G”. Generator “G” then interprets the signal received from accelerometer 124 and, in turn, transmits a corresponding dissecting electrosurgical energy output (i.e., specific power and waveform associated with dissecting), via transmission wire 114, to electrocautery blade 106.

[0032] On the other hand, if the surgeon moves electrosurgical pencil 100 in a direction orthogonal to the X axis, for example, as indicated by double-headed arrow “Z” in FIG. 1, accelerator 124 transmits a corresponding signal, through control loop 116, to generator “G”. Generator “G” then interprets the orthogonal signal received from accelerometer 124 and, in turn, transmits a hemostatic electrosurgical energy output (i.e., specific power and waveform associated with hemostasis), via transmission wire 114, to electrocautery blade 106.

[0033] Accordingly, the electrosurgical pencil of the present disclosure will enable a surgeon to control the type of output and/or the amount of energy

delivered to electrocautery blade 106 by simply moving electrosurgical pencil in a particular pattern or direction. In this manner, the surgeon does not have to depress any buttons or switches which are disposed on the electrosurgical pencil 100 in order to produce either a dissecting or hemostasis energy output in electrocautery blade 106. As can be appreciated, the surgeon does not have to adjust dials or switches on generator "G" in order to produce either the dissecting or hemostasis energy output in electrocautery blade 106.

[0034] Accelerometers suitable for position sensing or electrostatic forcing may be formed with fixed and movable electrodes in many configurations. Several embodiments of accelerometers having in-plane motion sensitivity are shown in FIG. 2, along with an orthogonal coordinate system. In particular, as seen in FIGS. 2A-2C, a differential parallel plate accelerometer is shown generally as 150. Differential parallel plate accelerometer 150 includes an electrode 152, attached to a proof mass 154, which is movable along the Y-axis thereby changing the gap between movable electrode 152 and fixed electrodes 156 and 158. Motion of movable electrode 152, along the Y-axis, causes opposite changes in capacitance formed by electrode pair 152, 156 and 152, 158. In FIG. 2B, a balanced, interdigitated comb-finger accelerometer is shown generally as 160.

[0035] Balanced, interdigitated comb-finger accelerometer 160 includes an electrode 162, attached to a proof mass 164, which is movable along the Y-axis thereby changing the overlap area between movable electrode 162 and a fixed wrap-around electrode 166. In FIG. 2C, an offset, interdigitated comb-finger

accelerometer is shown generally as 170. Offset, interdigitated comb-finger accelerometer 170 includes an electrode 172, attached to a proof mass 174, which is movable along the Y-axis thereby changing gaps between movable electrode 172 and a fixed wrap-around electrode 176.

[0036] While a single accelerometer 124 which can measure changes in the acceleration of electrosurgical pencil 100 in the axial (i.e., X-direction), lateral (i.e., Y-direction) and vertical (i.e., Z-direction) directions is preferred, it is envisioned that a pair of identical accelerometers or different accelerometers (i.e., accelerometers 150, 160 and 170), as shown in FIGS. 2A-2C, can be used. For example, a first accelerometer, such as, offset interdigitated comb-finger accelerometer 170, can be mounted within electrosurgical pencil 100 such that a displacement of movable electrode 172 in the Y-direction results in the transmission of dissecting electrosurgical energy by generator "G" to electrocautery blade 106 while a second accelerator, such as, another offset interdigitated comb-finger accelerometer 170, can be mounted within electrosurgical pencil 100, orthogonal to the first accelerometer, such that a displacement of movable electrode 172 in the X-direction results in transmission of hemostatic electrosurgical energy by generator "G" to electrocautery blade 106.

[0037] It is envisioned that any combination of accelerometers can be provided in electrosurgical pencil 100 in any number of orientations to measure changes in acceleration in any number of directions including rotational acceleration (Y-direction and Z-direction). It is also envisioned that any

combination of accelerations in the X-direction, Y-direction and Z-direction can also be detected, measured and calculated to effect the electrosurgical output from Generator "G".

[0038] In addition to accelerometers, it is envisioned that many other types of sensors for detecting movement of electrocautery blade 106 can be provided. Other types of force-sensing transducers may be used. Other types, including and not limited to, optical positioning systems, radiofrequency positioning systems, ultrasonic positioning systems and magnetic field positioning systems may be used.

[0039] While an active electrode in the form of a blade has been shown and described, it is envisioned that any type of tip can be used as the active electrode of electrosurgical pencil 100. For example, the active electrode can be an elongated narrow cylindrical needle which is solid or hollow with a flat, rounded, pointed or slanted distal end.

[0040] It is further envisioned that the amount of time required for the transmission of electrosurgical energy from the generator "G" to the electrocautery blade 106, in response to an output signal received from the accelerometer 124 can be adjusted based on the degree of responsiveness desired by the surgeon. For example, a relatively shorter response time would be considered more responsive than a relatively longer response time.

[0041] In addition, it is envisioned that the accelerometer 124 be provided with motion detection algorithms which transmit energy cut-off signals to

generator "G" if electrosurgical pencil 100 is held motionless or laid down for an extended period of time. It is contemplated that the sensitivity to activation of electrosurgical pencil 100, in response to an axial, vertical or transverse movement, may be decreased as time lapses from the last time that electrosurgical pencil 100 was used. As such, electrosurgical pencil 100 would be less likely to be inadvertently activated as more time elapses. In addition, the ability to disable the electrosurgical pencil 100 when not in use improves the clinical safety of the device. The motion detection algorithm effectively creates a "virtual holster" which keeps electrosurgical pencil 100 from being inadvertently activated.

[0042] Turning now to FIGS. 3 and 4, there is set forth a partially broken away perspective view of an electrosurgical pencil constructed in accordance with another embodiment of the present disclosure and generally referenced by numeral 200. Electrosurgical pencil 200 is similar to electrosurgical pencil 100 and will only be discussed in detail to the extent necessary to identify differences in construction and operation.

[0043] As seen in FIGS. 3 and 4, electrosurgical pencil 200 includes a film-type accelerometer or sensor 224 supported in housing 102. Sensor 224 is preferably includes substrate 226 fabricated from an elastomeric material. Sensor 224 further includes an array of electrodes 228 (in the interest of clarity only four electrodes 228a-228d have been shown) positioned around the periphery of substrate 226. Sensor 224 further includes a proof mass 230 electrically connected to each electrode 228 via electrical leads 232. Proof mass

230 is movable in any direction along axes X, Y and Z thereby changing the gap distance between itself and electrodes 228 and the resistance through leads 232.

[0044] Accordingly, motion of proof mass 230, along the X, Y and/or Z axis results in transmission of a particular signal, through control loop 116, to generator "G" (see FIG. 1). Generator "G" then interprets the particular signal received from sensor 224 and, in turn, transmits a corresponding distinct electrosurgical energy output (i.e., specific power and/or waveform), via transmission wire 114, to electrocautery blade 106.

[0045] For example, with activation button 126 depressed, movement by the surgeon of electrosurgical pencil 200 is directions along the X axis (i.e., in a stab-like motion), causes sensor 224 to transmit a first characteristic signal to generator "G". Generator "G" interprets the first characteristic signal and, in turn, transmits a corresponding dissecting electrosurgical energy output (i.e., a specific power and a specific waveform associated with dissecting), to electrocautery blade 106.

[0046] In a further example, with activation button 126 depressed, movement by the surgeon of electrosurgical pencil 200 in directions transverse to the X axis, such as, for example, along the Y and/or Z axes, causes sensor 224 to transmit a second characteristic signal to generator "G". Generator "G" interprets the second characteristic signal and, in turn, transmits a corresponding hemostatic electrosurgical energy output (i.e., a specific power and a specific waveform associated with hemostasis), to electrocautery blade 106.

[0047] It is envisioned that substrate 226 has a concave-like configuration. In this manner, when the surgeon holds electrosurgical pencil 200 still, proof mass 230 will have a tendency to return to the bottom of substrate 226 and effectively reset itself automatically. In other words, a concave-like substrate 226 can be self-centering and thus provide electrosurgical pencil 200 with a self-resetting capability. It is also envisioned that other shapes may be used.

[0048] Accordingly, the electrosurgical energy output of electrosurgical pencils 100, 200 will be controlled by the natural movements of the surgeon's hand and no specific thought is required to change the corresponding energy output from a "dissecting" setting to a "hemostatic" setting and vice-a-versa.

[0049] It is envisioned that when electrosurgical pencil 100, 200 is held motionless for a predetermined amount of time and/or below a predetermined threshold level of movement (i.e., accelerometer 124 and/or sensor 224 do not sense movement of electrosurgical pencil 100 or 200 for a predetermined period of time and/or sense movement which is below a predetermined threshold level), electrosurgical generator "G" does not transmit electrosurgical energy to the electrocautery blade. It is further envisioned that the sensitivity of electrosurgical pencil 100 or 200 can be increased and/or decreased by adjusting the threshold levels of time and movement accordingly.

[0050] It is further envisioned that electrosurgical generator "G" begins and/or resumes supplying electrosurgical energy to the electrocautery blade when accelerometer 124 and/or sensor 224 detects a movement of

electrosurgical pencil 100 or 200 after the predetermined period of time has elapsed and/or after the predetermined threshold level has been surpassed.

[0051] From the foregoing and with reference to the various figure drawings, those skilled in the art will appreciate that certain modifications can also be made to the present disclosure without departing from the scope of the present disclosure. For example, embodiments of the present disclosure include an electrosurgical pencil having a button for controlling the electrosurgical energy output, in addition to the sensor or sensors discussed above. While embodiments of electrosurgical instruments according to the present disclosure have been described herein, it is not intended that the disclosure be limited there and that the above description should be construed as merely exemplifications of preferred embodiments.